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COMPUTER-AIDED-DESIGN OF THE HYDRAULIC SYSTEM
OF THREE-DIMENSIONAL CARTRIDGE VALVE BLOCKS
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COMPUTER-AIDED-DESIGN OF THE HYDRAULIC SYSTEM OF THREE-DIMENSIONAL CARTRIDGE VALVE BLOCKS

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Abstract This paper describes a 3D-CAD system for cartridge valve blocks design on 16 bit microcomputer. This system enables the possibility of generating detailed engineering drawings of any angles or any cross sections.

Key Words: computer-aided-design, cartridge valve hydraulic system

I. Introduction

In the hydraulic computer-aided-design (CAD) field, the CAD of the hydraulic system of cartridge valve has always been a topic of intensive study. The graphic capability of the computers not only enables the spatial arrangement of the components of the cartridge valve blocks to be done in a smoother way and relieves the design engineers from the tedious, and trouble-causing, task, it also advances the research of the cartridge valve blocks.

The computer graphic capability has gone through great breakthroughs as a result of the improvements of the hardwares of the computers. Nowadays, the three-dimensional (3-D) graphics has replaced the two-dimensional (2-D) one that was used just a few years ago. This would mean great advantage for the study of the hydraulic system of cartridge valves. The 3-D space provides an integral and precise geometric model and renders the CAD technique more effective, more direct, and easier to comprehend. Judging from the present advancement in CAD of cartridge valve blocks, most of the

3-D drawing softwares are developed on the 32-bit machines and little progress has been reported for the 16-bit machines. Even the AutoCAD is a two-and-a-half-dimensional (pseudo three-dimensional) program.

A large amount of research on the CAD of cartridge valve blocks were done by the foreign companies and institutes. The Vickers Company first introduced the CAD/CAM software for the design of valve blocks. The exchange-type hydraulic cartridge valve block design package HYBLO-CAD/CAM was introduced by Tanopere University in Finland. And the HYKON software package was introduced by Aachen Industrial University. Among them, the package which received the most attention is the 3-D CAD cartridge valve block design package developed by the Hamburg-Harberg Technology University of West Germany based on the true 3-D graphic system PROREN 2. It was claimed that this cartridge valve block design package based on the true 3-D system was the most advanced in the world (in 1987) and the 3-D model of the cartridge valve hydraulic system and the output of the drawings of the cross sections were almost perfect. In this country, similar researches have been conducted in Jiaotong University in Shanghai and the Dalian College of Engineering. However, these researches were all under the condition of two-dimension.

According to the present situation, the 16-bit machines (such as IBM) is the main stream in the next 5 to 10 years. Therefore, it makes a lot of sense to develop the "semi-CAD work station" on the 16-bit microcomputers. The Fluid Transporting and Control Institute of Zhejiang University has taken the 7.5 national research topic and, using AutoCAD software as the basis, developed the design package of 3-D cartridge valve blocks on IBM PC/AT. To realize the 3-D displaying of cartridge valves, the secondary development of the plotting software was performed based on LISP language

and the tool box of 3-D structures of cartridge valve blocks was established based on the variable-parameter technique. Moreover, the difficulties in transforming from the 3-D graphics to the engineering plots of the various parts were solved by the "knowledge-base inlay" method. And finally, the engineering plots of these parts were produced by the hydraulic system engineering graphic generating system (EGS) that was already available.

II. 3-D Valve Structure Tool Box

To proceed with the design work of cartridge valve block hydraulic systems, the first step is to solve problems with the 3-D graphics on the monitor screen. The 3-D surface and 3-D curve functions provided by AutoCAD enables us the capability of displaying 3-D structural figures. Since the cartridge valve blocks are highly standardized, (a standard cartridge is composed of the spatial elements such as hole passage, stair holes, thread holes, machine holes (including thread plug), standard insertion holes and the rectangular blocks), the key to the successful 3-D displaying of cartridge valve blocks is the establishment of the tool box CVTOOLS which composed of all the spatial elements.

Based on the fundamental plotting softwares available, displaying of each spatial element was accomplished by the "curvilinear surface composition" method. The so called "curvilinear surface composition" method indicated that all the spatial elements were composed of many "curvilinear surfaces". For example, the hole passage was made by the composition of many long and narrow rectangular surfaces to make a cylindrical surface and the thread hole and insertion hole were composed of many cylindrical and conical surfaces. The spatial elements constructed based on the curvilinear

surface method generally exhibit more 3-D features and higher processing speed can be guaranteed. The flow chart of the construction of spatial element is shown in figure 1. It should be noted that the insertion hole is actually the combination of other elements; namely, a series of hole passages and thread holes.

If these basic spatial elements were analyzed, it can be found that they all have one common feature. That is, for the similar spatial elements with different passage dimensions or rated values, their shapes are basically the same or even identical in some cases. This provides the basis for the establishment of the spatial element tool box using the variable-parameter tool-box establishment technique. The basic idea of the variable-parameter tool-box establishment technique is to adopt some standard dimension (such as the diameter) to be the operating function, and during a drawing process a multiple sets of different variables will be given quantities in order to obtain the shapes required by its users. If the design of the spatial element tool-box is based on this variable-parameter technique, the structure of the tool box can be optimized and the redundancy in data can be reduced and, at the same time, the integrity and completeness of the spatial element tool-box can be guaranteed. The structure of the tool box of spatial elements based on this kind of design method is shown in figure 2.

Since the spatial element tool-box is designed to fulfill the purpose of 3-D displaying of cartridge valve blocks, it is also called the 3-D valve block structure tool-box. In this tool-box, the "passage dimension" indexing method was adopted so that, under the support of the menu system, the users could obtain the element figure in the spatial coordinate system

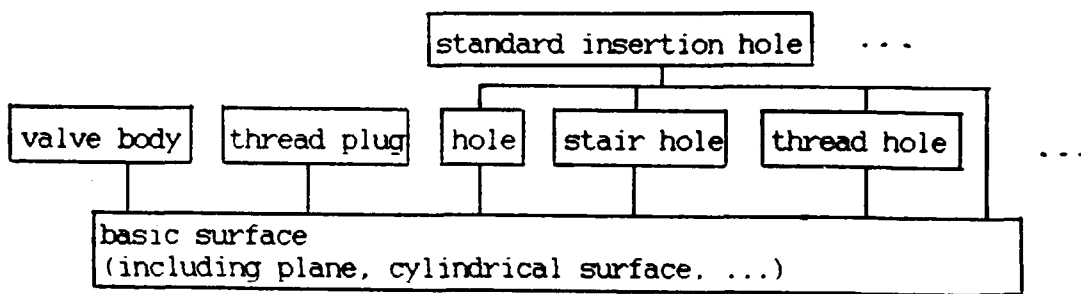


Figure 1: Flow chart of the formation of spatial figure elements

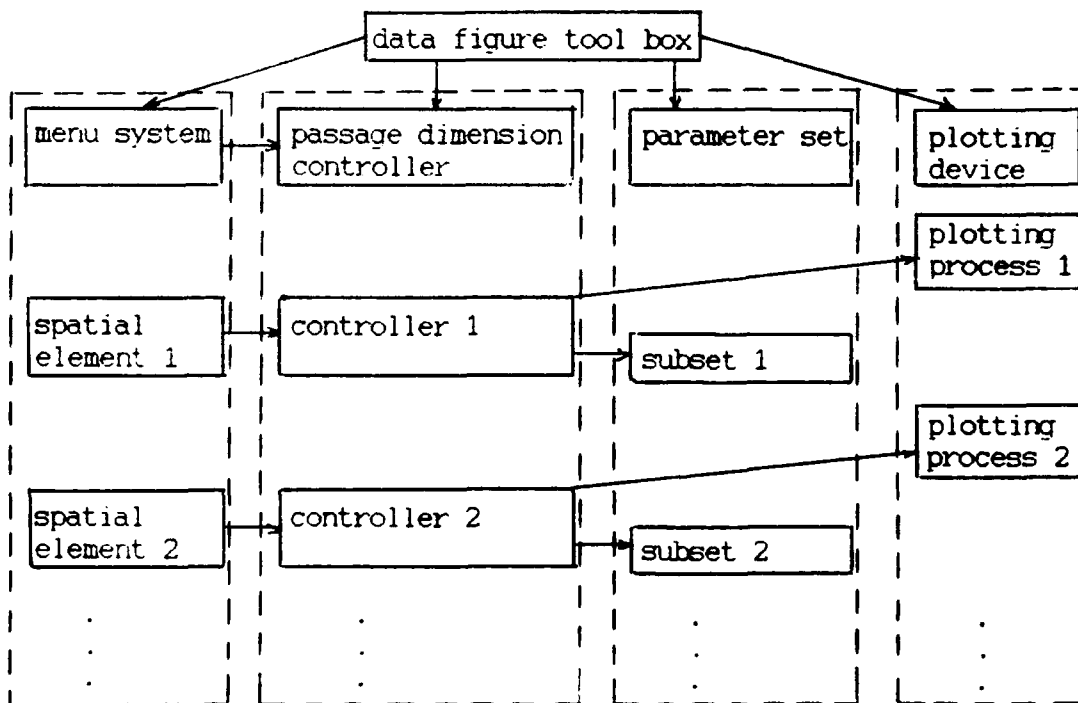


Figure 2: Illustration of the structure of spatial figure element tool box

by giving limited number of data such as the value of the diameter and the spatial positions.

III. The Application of "Knowledge-Base Inlay" Method

One of the major problems encountered in the 3-D CAD softwares is the transformation from the 3-D drawing of the cartridge valve blocks based on the CVTOOLS spatial elements to the engineering plots of the parts which shall be used in the actual manufacturing process. Only when the plotting of the engineering plots can be done automatically can the greatest potential of CAD technology be fully appreciated. In the development process of this software package, the "knowledge-base inlay" method was utilized so that each elements in the figure could be analyzed and arranged according to the specified rules and, at the same time, formed the basis for the output of the engineering plots.

During the plotting of the engineering plots of the individual parts, the distinguishing of the spatial figure elements and the extrapolation from the displaying in the 3-D plot to the section plot are one of the key issues for the automatic generation of the engineering plots. For example, for a figure element (such as an insertion hole), a judgement process should be taken to determine its spatial position and its spatial representation (whether solid line or dotted line should be used) in the front-view plot, top-view plot, and side-view plot. The "knowledge-base inlay" method introduces the specified rules in the usual routine process and forms the basis of the knowledge-base judgement structure so that the correct cross sectional representation of the spatial figure can be correctly determined.

The AutoLisp language system in the AutoCAD software provides the most general set of rules of the generation-type system principles. The general form of the set of rules of the generation-type system principle can be expressed as:

```
[rule] m
  if (fact 1 is triggered to be true)
    (fact 2 is triggered to be true)
    .
    .
    .
  then (conclusion fact 1 is activated)
    (conclusion fact 2 is activated)
    .
    .
    .
```

Under the support of the set of rules, the process for the automatic generation of the engineering plot is as follows: First the spatial figure elements should be obtained and the a table of these elements should be prepared. In this table, the important characteristics of all the spatial figure elements of the cartridge valves should be listed such as the position, name of the figure elements, passage dimensions, and the direction of arrangement. Based on the elements listed in this table, the rules can be applied to distinguish and determine the representation of the figure elements in various figures of different views. In case that the plots of cross-sectional view should be prepared, the user can specify any cross section and, by the correct application of the rules, the elements that would appear on the cross sectional plot can be determined and the correct way of representation can be decided. Then the plotter can be used to plot the engineering plots of various parts. This whole process is illustrated in figure 3.

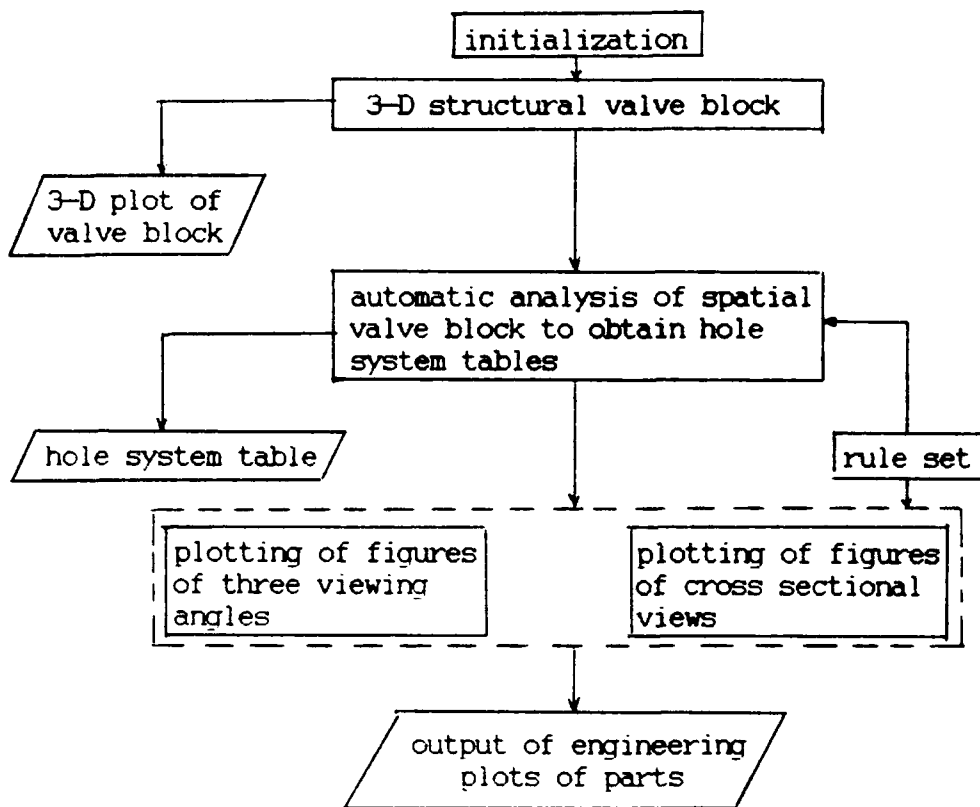


Figure 3: Flow chart of the automatic generation of engineering plots for parts.

The application of the "knowledge-base inlay" method provides the decision-making capability of the usual process and makes the CAD software more powerful. Since the set of rules is only used to analyze the figure elements and determine the representation of them in the various plots, there is no need to compile a complete knowledge-editing system or a human-machine interface such as those required in a general expert system. And in this way, the system can be made more agile and convenient to use to match most engineering CAD systems. Also, since it requires very little memory and the cost is less and since it can be accomplished by the fundamental structures of the intelligence language, this system has been benefiting us a lot.

IV. The CAD Software of 3-D Cartridge Valve Blocks

The purpose of CAD software of 3-D hydraulic cartridge valve blocks is to provide the spatial structural tools for the 3-D cartridge valve blocks so that the user can generate the figures of spatial valve blocks and then a table containing the spatial arrangement and characteristics of these figure elements. According to this table, the judgement of these elements can be performed and then either the plots from three different viewing angles can be produced or the cross sectional figures of any cross section specified by the user or the table of hole system can be made. This software consists of four parts: the first part is the tool box of the spatial valve block structures which is controlled by the menu and the generation of 3-D valve structure can be easily accomplished; the second part is the module for the acquirement of the spatial valve block informations so that the treatment of any valve block specified by the user can be conducted to obtain the spatial arrangement of the hole systems and

the technical data of each figure elements and output the information list CVLIST and the valve block hole systems required by the user; the third part carries out the judgement based on the CVLIST spatial figure element characteristics to determine the representation of these spatial elements on the plots based on the three different viewing angles and any cross sectional plots specified by the user; the fourth part is the engineering plotting module which generates the output for the required engineering plots. The structure of the entire software is illustrated in figure 4.

One of the applications of this 3-D valve block CAD software is the design of the quadruple bypass valve. First, the outer dimensions of this valve block were given to obtain a valve block body in the space. Then the four insertion holes were arranged in a reasonable manner and the oil line was laid out according to the requirements. In this manner, the 3-D spatial figure of the valve block was obtained. Observation of this valve block from various angles was made possible by coordinate transformation. Also, localized magnification can be applied to clearly observe the detailed parts of the valve block. In case any errors or bad arrangement should be detected, the modification can be made immediately. Once it was certain that the design was correct the automatic design procedure can be activated to generate the engineering plots of the parts. Utilizing this software, the engineers can complete the design of the valve block in a very short time and the engineering plots that are actually used in manufacturing can be obtained. Figure 5 is the 3-D figure of this quadruple bypass valve. It is clear that the three-dimensional feeling created is very good. Figure 6 is the engineering plots of the various parts.

V. Conclusions

key: 1 - rule set

2 - acquirement of hole system tables

3 - output of hole system tables

4 - plotting of figures of three viewing angles

5 - correction of engineering plots

6 - blackboard

7 - plotting of figures of cross sectional views

8 - construction of spatial valve blocks

9 - 2D, 3D figure sets

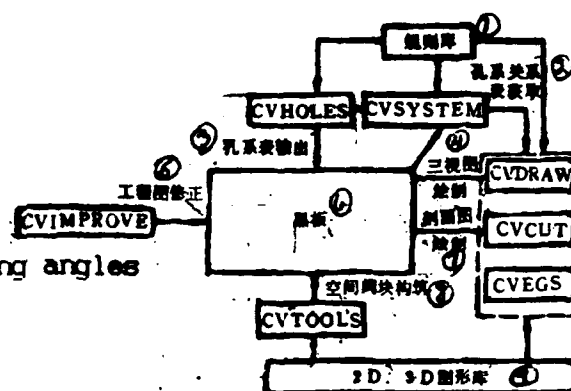


Figure 4: Illustration of CAD softwares for valve blocks

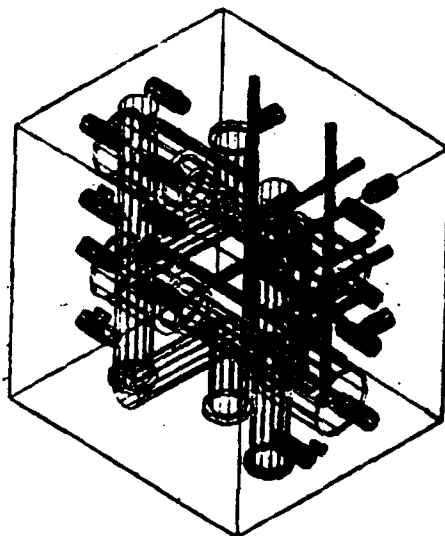


Figure 5: 3D figure of quadruple bypass valve block

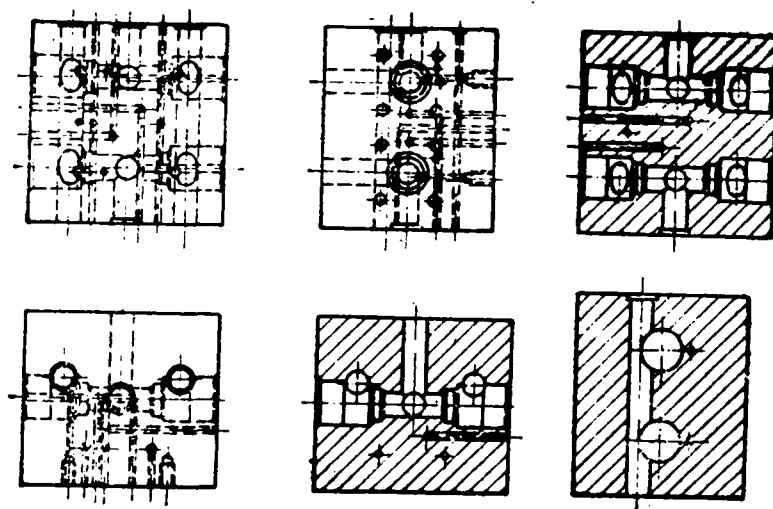


Figure 6: Engineering plots of the parts of quadruple bypass valve

The 3-D hydraulic cartridge valve block CAD software is a new software developed by the Fluid Transmission and Control Institute of Zerjiang University after the completion of FPTC-CADS software. This software enables the engineers to carry out the spatial design of valve blocks directly on the 16-bit microcomputers. Once the design is completed, the engineering plots of the parts of the valve blocks can be generated automatically. In this way, the efficiency in the design work can be greatly improved and the labor and working hours of the engineers can be reduced. Along with the wide application of the hydraulic cartridge valve and the amendment and improvement of this software in actual application, even higher efficiency can be expected from this software.

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NNCC AUTOMATIC PROGRAMMING SYSTEM FOR NON-CIRCULAR CURVES

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Abstract NNCC automatic programming system for non-circular curves can automatically make NC program of non-circular mathematic and list curves for working plane cams. This paper introduces the use, principle and operation of the system.

Key words: non-circular curves, automatic programming system

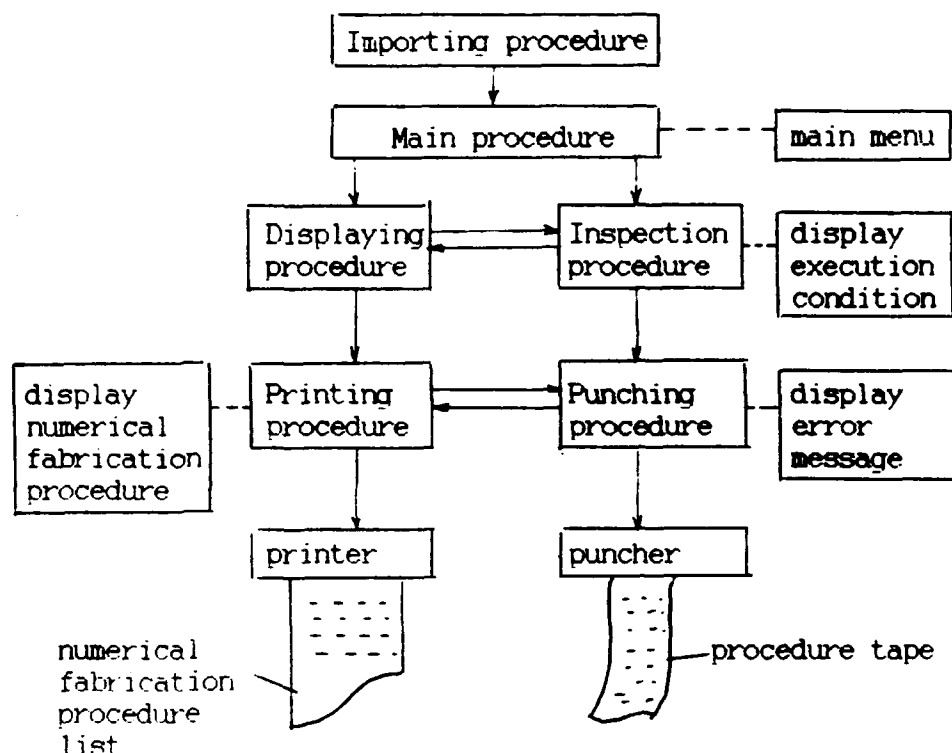
Among the four plane cams of the mark-pasting machine and the RME-B30/350 bottle-washing machine of the 20000cans/hour canned beer production line imported from the Federal Republic of Germany, three of them are the smooth non-circular contours composed of polar coordinate points and the fourth one is a smooth contour composed of arcs and four sections of coordinate curves. Among them, the cam of the bottle-washing machine is a keyless part purchased from Germany. The cams of the mark-pasting machine are the major elements for the smooth operation of 1) application of the paste, 2) obtaining of the mark, 3) clamping of the mark, and 4) pasting of the mark and the flawless operation of these steps is important when the smooth operation of the mark-pasting machine is required. There are 40 and 120 coordinate points for the cams of the bottle-washing machine and the mark-pasting machine, respectively. From the shapes of these cams, it is not possible to rely on hand calculation to program the numerical control procedures. In order to make the NC fabrication procedure of these cams to

be possible on the CNC 5VC lathes of the Numerical Control Center and to realize the domestic production of the cams of the bottle-washing machine made in Germany and to improve the quality of the mark-pasting machine. we have developed a NNCC automatic programming system for the non-circular curves on the M10 microcomputers. Using this system, 15 minutes after the raw coordinate data were given, the NC fabrication procedure for the smooth curve, formed by connecting the 120 coordinate points of the cams of the mark-pasting machine, can be prepared, the NC procedure list can be printed, and the procedure tape can be punched. Afterwards, this system was transported to IBM PC/AT and only a few minutes was required to prepare the NC procedure list and punch the procedure tape.

For other mathematical curves such as elliptic curves, parabolic curves, hyperbolic curves, rose curves, Archimedes' spirals ... etc, it was only required to input the related parameters to the computer and after a few minutes the NC procedure list and the procedure tape can be prepared.

The NNCC system is illustrated in the attached figure and is composed of the importing procedure, main procedure, displaying procedure, inspection procedure, printing procedure, inspection procedure and punching procedure.

Importing Procedure: The purpose of the importing procedure is to provide the programmer with the menu of the required curves. Its main function is to establish the numerical data that is required by the main procedure. There are various kinds of importing procedures such as the elliptical curve importing procedure, spiral curve importing procedure, rose curve importing procedure, tabulated curve importing procedure ... etc.



Block diagram of NNCC non-circular curves programming system

Main Procedure: The purpose of the main procedure is to input the numerical data established by the importing procedure and output the data for numerical control (which is the numerical control fabrication procedure). It calculates the radii and center coordinates of the arcs, the coordinates of the insertion points, and the coordinates of the quadrant cross-over points that are necessary to link up the coordinate points to form a smooth curve. Then the center coordinates, coordinates of the insertion points, coordinates of the beginning points and end points of the arcs, and the coordinates of the quadrant cross-over points will be transformed into the proper form and proper functional code that are required by the numerical fabrication center so that the output of the

fabrication procedure can be directly fed to the numerical control system of the lathe and used in the NC fabrication process.

Displaying Procedure: The main purpose of the displaying procedure is to display the numerical control fabrication procedures on the computer screen to fulfill the reading, inspection, correction, and supplementing purposes.

Inspection Procedure: The purpose of the inspection procedure is to provide a safety inspection for the programmed numerical control fabrication procedures. It will examine the range of movement of the lathe (cutting tools) in each procedure and check if the movement will exceed the allowable range. It will also print out the questionable procedures and the coordinates which exceed the allowable range.

Printing Procedure: The purpose of the printing procedure is to output, in the form of numerical control procedures list, the numerical control fabrication procedures. (after inspection by the programmers and proper safety test), so that the operators and related personnel can read through them.

For the coordinate curves, the NNCC can only be carried out after the raw coordinate data were given. For the non-circular curves represented by the mathematical formulae, the NNCC can be carried out immediately after the computer is turned on. After entering NNCC, the following will be shown on the screen:

GUANGDONG LIGHT INDUSTRIAL MACHINERY WORKS

Auto-programming Subsystem

On Machining Center

* N N C C *

Non-circular Curves

Press Any Key to Continue

After pressing any key, the control will be transferred to the importing procedure and the main menu of the importing procedure will be shown:

MAIN MENU

- 1Ellipse (Hole)
- 2Ellipse (Shaft)
- 3Rose Curve
- 4Archimedes Spiral
- 5Edge or Slot Can
- 6Lens
- 7Arcs Tangential TO Intersecting Lines
- 8Display, Print or Punch NC & Data Files
- 9Check NC files for Safety
- 10End

Select Number Desired, then Press Enter.

The programmers will select the desired curves from the main menu, and after pressing the enter key, the execution of the program will continue and the data generated by the program will be output to the exterior storage unit. After the importing procedure is completed, the control will be transferred to the main procedure and the execution of the program continues.

During the execution of the main procedure, according to the prompt by the computer screen, the information such as the data of the cutting tools

and the constrained arcs at the turning point of the curves (the arcs constrained by the diameter of the cutting tools) should be given for the continued execution of the program. At the mean time, the execution condition of the program will be displayed on the screen. In case the difference between the coordinates of the arc-supplementary and the coordinates of the arcs exceed the allowed value, or if the radii of the constrained arcs are less than the radii of the cutting tools, the error message will be displayed on the screen and the execution of the main procedure will be terminated.

The operation of the main procedure uses the exterior storage units (hard diskette or floppy diskette) as the I/O device. The numerical control fabrication procedures generated by this procedure are also stored in these exterior units.

After the numerical control procedure document is completed, the main procedure will continue to show the following menu on the screen:

```
1 .....Displaying Your NC-file for Recorrecting
2 .....Check NC file for Safety
3 .....Punchout
4 .....Print Out
Type in the Number Desired
```

According to the prompt on the screen, the operator can choose to display or correct the established numerical control fabrication procedures, or to perform safety inspection. The sequence can also be selected by the operators.

After the displaying and inspection procedures are completed, the following menu will be shown on the screen:

The menu after displaying procedure:

SCheck for Safety
DDisplay or Print Another Datafile
RReturn to Main Menu
GGoto Punch Tape Out
EEnd

The menu after the inspection procedure:

PPrinting or Displaying
CCheck Another NC-Datafile
GGoto Punch Out
RReturn to Main Menu
EEnd

From this menu list, the operator can choose either to print the procedure list or to punch out the procedure tape.

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